

WHAT IS CLAIMED IS:

1. A method of monitoring machining in an electrochemical machining tool assembly having first and second tools arranged on opposite sides of a workpiece so as to define first and second gaps with said workpiece, said method comprising:

5 mounting a first ultrasonic transducer in said first tool;
mounting a second ultrasonic transducer in said second tool;
generating ultrasonic waves with said first and second ultrasonic transducers;

10 detecting arrival times of reflections of said ultrasonic waves at said first and second ultrasonic transducers; and
using said arrival times to calculate at least one of said first gap size, said second gap size, and thickness of said workpiece.

2. The method of claim 1 wherein said step of detecting arrival times includes;

15 detecting a first arrival time of an ultrasonic wave reflected from said first tool;

detecting a second arrival time of an ultrasonic wave reflected from a first side of said workpiece;

20 detecting a third arrival time of an ultrasonic wave reflected from said second tool; and

detecting a fourth arrival time of an ultrasonic wave reflected from a second side of said workpiece.

3. The method of claim 2 wherein said step of using said arrival times to calculate at least one of said first gap size, said second gap size, and thickness of said workpiece includes calculating the ultrasonic time-of-flight in said first gap by subtracting said first arrival time from said second arrival time and calculating the ultrasonic time-of-flight in said second gap by subtracting said third arrival time from said fourth arrival time.

4. The method of claim 3 wherein said step of using said arrival times to calculate at least one of said first gap size, said second gap size, and thickness of said workpiece further includes calculating said first gap size by multiplying said first gap ultrasonic time-of-flight by the ultrasound velocity in said first gap and dividing the resulting product by two.

5. The method of claim 3 wherein said step of using said arrival times to calculate at least one of said first gap size, said second gap size, and thickness of said workpiece further includes calculating said second gap size by multiplying said second gap ultrasonic time-of-flight by the ultrasound velocity in said second gap and dividing the resulting product by two.

6. The method of claim 3 wherein said step of using said arrival times to calculate at least one of said first gap size, said second gap size, and thickness of said workpiece further includes:

calculating said first gap size by multiplying said first gap ultrasonic time-of-flight by the ultrasound velocity in said first gap and dividing the resulting product by two;

calculating said second gap size by multiplying said second gap ultrasonic time-of-flight by the ultrasound velocity in said second gap and dividing the resulting product by two; and

calculating said workpiece thickness by subtracting said first gap size and said second gap size from the distance between said first and second tools.

7. The method of claim 1 further comprising detecting a position of a machined portion of said workpiece relative to a workpiece datum.

8. A method of monitoring machining in an electrochemical machining tool assembly having first and second tools, said method comprising:

mounting a first ultrasonic transducer in said first tool;

mounting a second ultrasonic transducer in said second tool;
situating a workpiece between said first and second tools so as
to define a first gap between said first tool and said workpiece and a second
gap between said second tool and said workpiece;
5 connecting a source of electric power to said first and second
tools and to said workpiece;
flowing an electrolytic fluid through said first and second gaps;
generating ultrasonic waves with said first and second ultrasonic
transducers;
10 detecting a first arrival time of an ultrasonic wave reflected from
an interface between said electrolytic fluid and said first tool;
detecting a second arrival time of an ultrasonic wave reflected
from an interface between said electrolytic fluid and a first side of said
workpiece;
15 detecting a third arrival time of an ultrasonic wave reflected from
an interface between said electrolytic fluid and said second tool; and
detecting a fourth arrival time of an ultrasonic wave reflected
from an interface between said electrolytic fluid and a second side of said
workpiece; and
20 using said arrival times to calculate at least one of said first gap
size, said second gap size, and thickness of said workpiece.

9. The method of claim 8 wherein said step of using said
arrival times to calculate at least one of said first gap size, said second gap
size, and thickness of said workpiece includes calculating the ultrasonic time-
of-flight in said first gap by subtracting said first arrival time from said second
25 arrival time and calculating the ultrasonic time-of-flight in said second gap by
subtracting said third arrival time from said fourth arrival time.

10. The method of claim 9 wherein said step of using said
arrival times to calculate at least one of said first gap size, said second gap
size, and thickness of said workpiece further includes calculating said first
gap size by multiplying said first gap ultrasonic time-of-flight by the ultrasound
30 velocity in said first gap and dividing the resulting product by two.

11. The method of claim 9 wherein said step of using said arrival times to calculate at least one of said first gap size, said second gap size, and thickness of said workpiece further includes calculating said second gap size by multiplying said second gap ultrasonic time-of-flight by the ultrasound velocity in said second gap and dividing the resulting product by two.

12. The method of claim 9 wherein said step of using said arrival times to calculate at least one of said first gap size, said second gap size, and thickness of said workpiece further includes:

calculating said first gap size by multiplying said first gap ultrasonic time-of-flight by the ultrasound velocity in said first gap and dividing the resulting product by two;

calculating said second gap size by multiplying said second gap ultrasonic time-of-flight by the ultrasound velocity in said second gap and dividing the resulting product by two; and

calculating said workpiece thickness by subtracting said first gap size and said second gap size from the distance between said first and second tools.

13. The method of claim 8 further comprising applying an acoustic couplant between said first ultrasonic transducer and said first tool and applying an acoustic couplant between said second ultrasonic transducer and said second tool.

14. The method of claim 8 further comprising disconnecting said source of electric power while generating ultrasonic waves with said first and second ultrasonic transducers and detecting said arrival times.

15. The method of claim 8 further comprising regulating said source of electric power to minimize gas bubble generation on said first and second tools.

16. The method of claim 8 further comprising detecting a position of a machined portion of said workpiece relative to a workpiece datum.

5 17. An electrochemical machining tool assembly comprising:
first and second tools spaced apart from one another so that a workpiece can be located therebetween;

a first ultrasonic transducer mounted in said first tool;

a second ultrasonic transducer mounted in said second tool;

and

10 means for calculating gap sizes and workpiece thicknesses from arrival times at said first and second ultrasonic transducers of reflections of ultrasonic waves generated by said first and second ultrasonic transducers.

15 18. The assembly of claim 17 wherein said first tool defines a first cutting surface, said second tool defines a second cutting surface, and said first and second ultrasonic transducers are both located on an axis that extends normal to both of said first and second cutting surfaces.

19. The assembly of claim 17 wherein said first and second ultrasonic transducers comprise contact transducers.

20 20. The assembly of claim 17 wherein said first and second ultrasonic transducers comprise immersion transducers.

21. The assembly of claim 17 further comprising an acoustic couplant between said first ultrasonic transducer and said first tool and an acoustic couplant between said second ultrasonic transducer and said second tool.